NOLTR 65-114

DETONATION PRODUCTS OF OXYGEN DEFICIENT EXPLOSIVES (U)

U. S. Government Agencies may obtain copies
of this report direct from DDC.

NOL

25 OCTOBER 1965

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

NOLTR 65-114

(6) DETONATION PRODUCTS OF OXYGEN DEFICIENT EXPLOSIVES (U),

(w) /C. B. Root and J. N. Ayres.

Mild detonating fuse containing oxygen deficient explosives such as DIPAM and RDX showed considerable formation of carbon monoxide when fired in the absence of atmospheric oxygen. As might be the case in space or high altitude applications, and depending on the total amount of explosive, the detonation products of MDF loaded with oxygen deficient explosives could contain sufficient carbon monoxide to be harmful to human beings. A method is given for estimating the toxicity from carbon monoxide and carbon dioxide when oxygen deficient explosives are detonated in confined structures.

25 Oct 65

(12) 15 p.

(17) NOL-787/NOL P

EXPLOSION DYNAMICS DIVISION
EXPLOSIONS RESEARCH DEPARTMENT
U.S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

NOLTR 65-114   25 October 1965

DETONATION PRODUCTS OF OXYGEN DEFICIENT EXPLOSIVES (U)

This work was performed as a result of interest in the products
of detonation of a heat resistant explosive, DIPAM. This
explosive has application on the Navy F-111 aircraft and
possible application on NASA spacecraft. Investigations are
being made to determine the usefulness of new heat resistant
explosives in explosive components for future space programs
like APOLLO. This report discusses possible hazards from
DIPAM and RDX fired in oxygen deficient atmospheres.

The identification of commercial materials implies no criticism
or endorsement by the U. S. Naval Ordnance Laboratory.

                         J. A. DARE
                         Captain, USN
                         Commander

                         C. J. ARONSON
                         By direction

UNCLASSIFIED

TABLE OF CONTENTS

TABLES

FIGURES

UNCLASSIFIED

INTRODUCTION

Most new and conventional military explosives are oxygen deficient, i.e., they do not contain enough oxygen in their molecular structure to convert the carbon and hydrogen present to water vapor and carbon dioxide. For example, RDX (hexahydro-1,3,5-trinitro-5-triazine) is slightly oxygen deficient. Assuming the formation of H_2O, C, CO, and CO_2, in that order until all atoms of the reactant are utilized, it would give products as follows:

$$C_3 H_6 N_6 O_6 \longrightarrow 3 H_2O + 3 CO + 3 N_2 . \qquad (1)$$

DIPAM (3,3'-Diamino-2,2'4,4'6,6'-Hexanitrobiphenyl) a new heat resistant explosive developed at NOL is representative of a highly oxygen deficient explosive. DIPAM would react as follows:

$$C_{12} H_6 N_8 O_{12} \longrightarrow 3 H_2O + 9 CO + 3C + 4 N_2 . \quad (2)$$
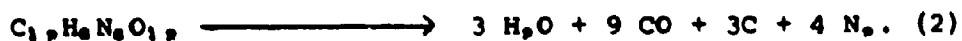
These simplified equations provide a very useful starting point for explaining the reaction products that actually occur. However, prevailing temperatures and pressures, the chemical species present, and the thermodynamic quantities of importance lead to complex mixtures of products. Afterburning (combination of partially oxidized detonation products with oxygen in the air) and other phenomena also complicate the picture. For example, the products of DIPAM loaded mild detonating fuse (MDF) have been noted to vary from black to light yellow in color depending upon detonation conditions.

DIPAM is being used in MDF and in flexible linear shaped charge (FLSC) for transmission of detonation from point to point and for cutting metals in missiles, aircraft, and spacecraft. In airplanes and spacecraft these operations are often carried out near the crew. According to the above equations a significant amount of carbon monoxide would be expected, particularly if there is little or no afterburning. Accordingly, we wished to determine what proportion of noxious or toxic gaseous products would be expected from the functioning of DIPAM-loaded MDF. We also wished to determine the effect of free volume and atmospheric oxygen on the make-up of the reaction products. Thus, the purpose of this work was to determine the nature of the products formed when oxygen deficient explosives are detonated in obturated mechanisms or structures using MDF or FLSC. Such information should be useful in deciding future applications of MDF and FLSC within capsules, space vehicles, and the like where the reaction products could impair human efficiency, or could even conceivably be lethal.

DETERMINATION OF GASEOUS DETONATION PRODUCTS

Apparatus

The firing chamber used is shown in Figure 1. A piece of MDF was wound around the grooved aluminum cylinder and attached to a detonator as shown. The depth of the groove was greater than the outside diameter of the MDF to protect the unreacted MDF from fragments as the detonation moved around the cylinder. The detonator consisted of a bridgewire in contact with 30 mg of dextrinated lead azide, followed by a 40 mg base charge of DIPAM pressed into a charge holder. The amount of explosive in the detonator was small compared to the amount of explosive contained in the MDF. (This will be discussed later in the text.)

After firing, a sample of the gases present in the chamber was collected in an evacuated flask via valve A. A thermocouple placed as shown was used to monitor the temperature inside the chamber before and after detonation. All gas samples were taken when the chamber contents had cooled to 40°C. The chamber, while not sealed, was essentially air tight.

To establish in the chamber the nitrogen atmosphere used in some tests, the bottom cap was loosened and the chamber flushed with nitrogen at 10 psig (fed in through valve A) for 10 minutes. The pressure inside the chamber was allowed to come to equilibrium with atmospheric pressure and the system closed for firing. The gas samples were analyzed for CO_2, CO. N_2, H_2, O_2, H_2O, and hydrocarbon content by a mass spectrometer at the Bureau of Standards. A tabulation of experimental variables and gas analysis results for seven experimental firings are given in Table I.

DISCUSSION

As shown in Table I, four DIPAM shots were fired and the gaseous products analyzed as described. The CO_2/CO ratio may be used as a rough index of the degree of afterburning which occurred. Since DIPAM is oxygen deficient we would not expect CO_2 to be formed unless oxygen were to be made available from some external source, note equation (2).

Sample A, the detonator alone fired in air, shows products so close to that of the room air composition that the contribution of the detonator to the overall product distribution was considered negligible. The same type of detonator was used in all shots.

The gaseous products from samples B and C show the difference in products when equal amounts of the same explosive
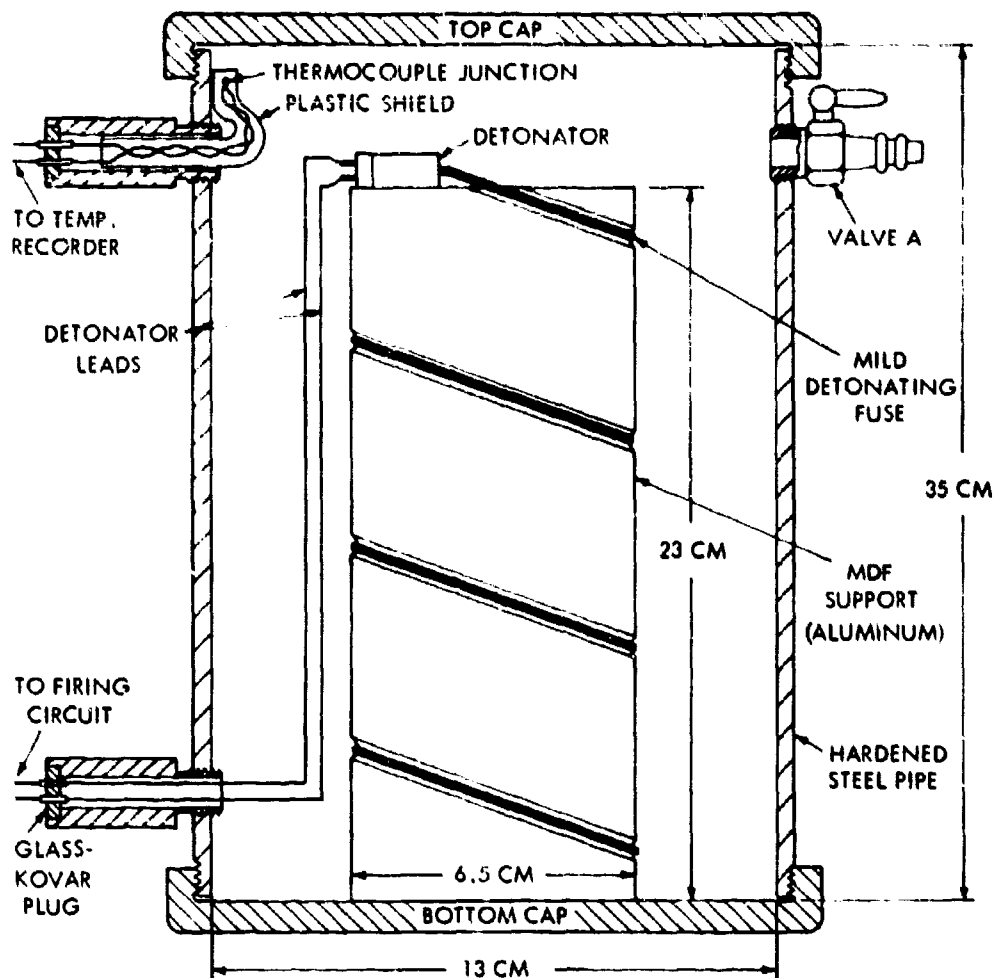
FIG. 1 APPARATUS FOR THE COLLECTION OF GASEOUS DETONATION PRODUCTS

TABLE I

STUDY OF GAS ENVIRONMENT EFFECT ON DECOMPOSITION PRODUCTS, TEST CONDITIONS AND RESULTS

					Test Identification			
		A	B	C	D	E	F	G
Chamber Conditions	Fill Gas	Air*	N₂	Air*	Air*	Air*	N₂	Air*
	Explosive	Detonator	DIPAM	DIPAM	DIPAM	DIPAM	RDX	RDX
	MDF Core Load (grains/ft)	—	15	15	2.1	15	10	10
	MDF Length (inches)	—	14	14	95	28	9.5	9.5
	Quantity of Explosive — grains	0.070	17.5	17.5	16.6	35.0	7.92	7.92
	Quantity of Explosive — grams	0.0002	1.134	1.134	1.077	2.268	0.513	0.513
	Quantity of Explosive — moles		0.0025	0.0025	0.0024	0.0050	0.0023	0.0023
	Moles O₂ in Chamber Atmosphere	0.045	0.0	0.045	0.045	0.045	0.0	0.045
	Mole Ratio: O₂/Explosive	225	—	18	19	9	—	20
Results	Mole Ratio CO₂/CO	2	0.5	65	35	1.2	0.8	65
	Color of Solids	Grey	Black	Yellow-grey	Yellow-grey	Black	Grey	Grey
	CO₂	0.2	2.6	13.0	13.9	16.3	1.6	12.8
	CO	0.1	4.9	0.2	0.4	13.1	1.9	0.2
	H₂O	1.1	1.2	2.2	1.7	1.3	1.0	1.2
	N₂	76.8	88.6	77.2	77.2	64.3	92.3	81.3
	O₂	20.9	2.3	6.9	5.9	1.0	1.6	3.2
	Ar	0.9	0.4	0.8	0.9	1.0	0.6	1.3
	H₂	—	—	—	—	2.7	1.0	—
	C₂H₂	—	—	—	—	0.3	—	—

*Gas Analysis of Environmental Air (mole %): $H_2O=0.9$; $N_2=77.4$; $O_2=20.8$; and $Ar=0.9$

are fired in air and in nitrogen atmospheres. The free oxygen
found in the products of the nitrogen atmosphere shot may have
resulted from a sampling error, incomplete flushing with
nitrogen prior to the firing, or even reentry of gas after
firing and during the cooling to $40^\circ C$. Note that in sample B
nearly all the available oxygen is utilized in the reaction,
as is indicated by the reduction of the free oxygen from
20.8 to 2.3 mole per cent. This indicates considerable after-
burning. The amount of carbon monoxide produced in the nitrogen
atmosphere (Test B) is 4.7 mole per cent greater than in the air
atmosphere (Test C). Thus the reaction product distribution
seems to approach equation (2) when atmospheric oxygen is not
available. A high carbon content in the products of the
nitrogen shot is predicted by equation (2) and is verified by
the black sooty residue found in the firing chamber. Sample A
yielded a light grey residue.

As might be expected, the available atmospheric oxygen
strongly affects the CO_2/CO ratio. As the available oxygen
decreases the ratio decreases. Comparing samples C and D
with sample E we find that the CO_2/CO ratio has changed from
~ 50 to ~ 1.2 as a result of doubling the total quantity of
explosives detonated in the same free volume. Comparing sample
E with sample B (no oxygen) the CO_2/CO ratio has further decreased
to ~0.5.

Note that in sample E products not otherwise observed were
found: acetylene and hydrogen. It is possible that these species
were formed because this was a larger explosion with a more
vigorous heat pulse that may have caused free radical combination
not possible or detectable in the lower powered shots.

Samples C and D show that no significant difference in
products results from different core load sizes of MDF. The
sheath to explosive ratio in both shots was approximately the
same as were the moles of explosive fired. Note the corresponding
similarity of products and CO_2/CO ratio.

Two shots were fired using RDX loaded MDF. These show that
RDX behaves in much the same manner as DIPAM when fired with
and without atmospheric oxygen being present. The carbon
monoxide content of the nitrogen atmosphere shot is not so
pronounced as with DIPAM since RDX is less oxygen deficient. As
predicted by equation (1) no significant free carbon was
formed in the oxygen deficient atmosphere since RDX contains
enough molecular oxygen to convert all of its carbon to
carbon monoxide.

Solid Detonation Products

The solid products produced when DIPAM MDF is detonated

take the form of fine powder interspersed with small particles
of free lead from the MDF sheath. Workers have observed smoke
and solids varying in color from light yellow to sooty black.
RDX, on the other hand, yields a grey powder under nearly all
conditions of detonation.

A qualitative explanation of the above differences in
products as a function of available oxygen in the atmosphere
may be postulated. Sample B, DIPAM fired in N₂, and sample E,
DIPAM fired in limited O₂, both exhibited black solid products
containing free carbon. Samples C and D , DIPAM fired in excess
air, exhibited lighter colored products with little or no free
carbon. Thus, in an abundance of oxygen, most of the carbon
not combined with molecular oxygen of the explosive does
combine with the atmospheric oxygen to eliminate free carbon in
the final products. The yellow hue noted in cases where excess
oxygen is available is probably caused by the presence of yellow
lead oxides formed by combination of the superheated lead sheath
with atmospheric oxygen during detonation.

A series of shots was fired in an essentially closed tube
in order to determine the oxygen/DIPAM ratio which causes the
transition from light to dark products. The ratio of air to
DIPAM was varied by firing different amounts of explosive in
the same volume of air. The DIPAM-MDF was initiated external
to the test chamber and then lead into it through a small hole.
This eliminated the effects of an initiator. The experimental
variables and results of this study are given in Table II.

The nature of the solid products changes between 1 and 2
moles of oxygen per mole of DIPAM. At greater concentrations of
air very little carbon is produced, and at lower concentrations
the residue is black indicating considerable unoxidized carbon.
This seems to indicate that a corresponding increase in carbon
monoxide present also starts to occur at this ratio of air to
DIPAM since the presence of free carbon in the gas analysis
shots correlated with higher carbon monoxide content in the
gaseous products.

There is one possible inconsistency between these results
and the ones shown in Table I:

Data from Table I		Data from Table II	
O₂/HE	Color	O₂/HE	Color
0	Black	0.67	Black
9	Black	1.0	Black
18	Yellow-Grey	2.0	Grey
19	Yellow-Grey	3.0	Yellow-Grey

TABLE II

DIPAM-MDF SOLID PRODUCTS VS ATMOSPHERIC OXYGEN

	Test Identification			
	H	J	K	L
MDF Core Load (grains/ft)	15	10	10	10
MDF Length (inches)	6	6	3	2
Quantity of DIPAM grains	7.5	5	2.5	1
grams	0.486	0.324	0.162	0.108
millimoles	1.057	0.714	0.357	0.239
Mole Ratio O_2/HE	0.67	1.0	2.0	3.0
Color of Solid Products	Black	Black	Grey	Yellow-Grey

Chamber Volume   85 milliliters

Gas Content (STP conditions)   3.43 millimoles

O_2 Content (at 20.8 mole %)   0.713 millimoles

Apparently the transition from black residues to yellow-grey
occurs at a much higher O_2/HF mole ratio for the larger free
volume experiment than for the smaller. However, the
differences in the two experiments may well have caused such
an apparent difference in results: the MDF in the Table I
experiment is in direct contact with the surface on which the
residue was collected while in the other it was at least a
centimeter away. The direct contact could quench the reactions
more quickly — thus requiring a greater amount of atmospheric
oxygen to be present to sustain the reaction.

Chamber Temperature Studies

In order to be able to withdraw samples consistently at
$40°C$, the temperature inside the gas analysis test chamber was
monitored during detonation. Figure 1 shows the thermocouple
placement. The temperature-time profiles for the various shots
are shown in Figure 2. As expected, the shots in the nitrogen
atmosphere exhibit lower temperature-time profiles since there
is no heating from afterburning. Considerable heat is apparently
generated in the afterburning process. No data are available for
sample E because the force of the detonation destroyed the thermo-
couple. The high chamber temperature recorded for the small
diameter DIPAM MDF (sample D) prompted a series of temperature
study shots. These were designed to determine whether higher
temperatures were generally achieved from small diameter MDF.

Figure 3 shows the apparatus used to determine the
temperature of the gases given off when various sizes of MDF
were fired. Redundant thermocouples were used to measure the
temperature of the detonation products forced through the vent
holes in the end of the chamber. The 90° bend in the chamber
prevented shrapnel damage to the thermocouples. The detonator
was placed outside the chamber so it would not contribute to
the measured effects. The area of the vent holes was large
compared to the hole through which the MDF was inserted. Thus,
most products were vented past the thermocouple upon detonation
of the MDF. Temperature was recorded as millivolts displayed
on a calibrated dual beam oscilloscope equipped with a
polaroid camera.

The results of firing six-inch sections of 2.1, 10, and
15 grains/ft DIPAM MDF are tabulated in Table III. The
temperature observed was found to be proportional to the amount
of DIPAM and/or the core load. (Figure 4.) Had there been a
disproportionately high temperature when the 2.1 grain/ft MDF
was fired (as was indicated by test D of Table I) then we would
not have expected to see the linear relationship shown in
Figure 4.
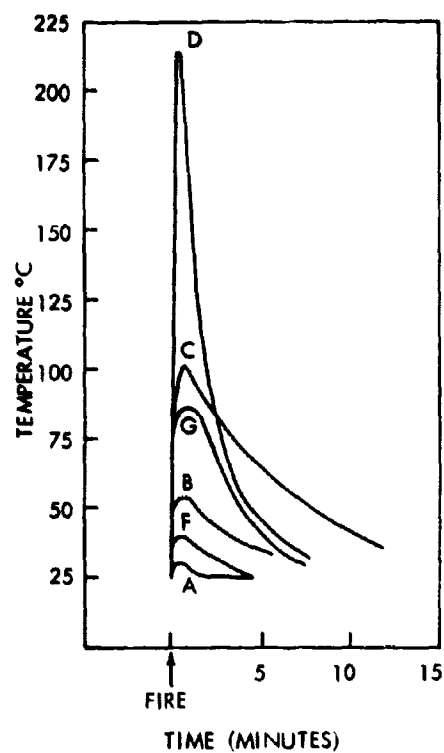
SAMPLE	MFD LENGTH (INCHES)	CORE LOAD (GRAINS/FT)	EXPLOSIVE	TOTAL EXPLOSIVE (GRAINS)	GAS ENVIRONMENT
A	DETONATOR ONLY				AIR
B	14	15	DIPAM	17.5	N_2
C	14	15	DIPAM	17.5	AIR
D	95	2.1	DIPAM	16.6	AIR
F	9.5	10	RDX	7.92	N_2
G	9.5	10	RDX	7.92	AIR

FIG. 2 TEMPERATURE PROFILES OF GAS ANALYSIS FIRINGS

MK 70 DETONATOR

DETONATOR AND MDF HOLDER (BRASS)

PIPE CAP

1" DIA BRASS PIPE

DIPAM MDF

PLASTIC INSULATION

THERMOCOUPLE JUNCTIONS

GLASS KOVAR CONNECTOR

THERMOCOUPLE WIRES

PIPE CAP

DUAL BEAM OSCILLOSCOPE

VENT HOLES

0° C REFERENCE JUNCTION
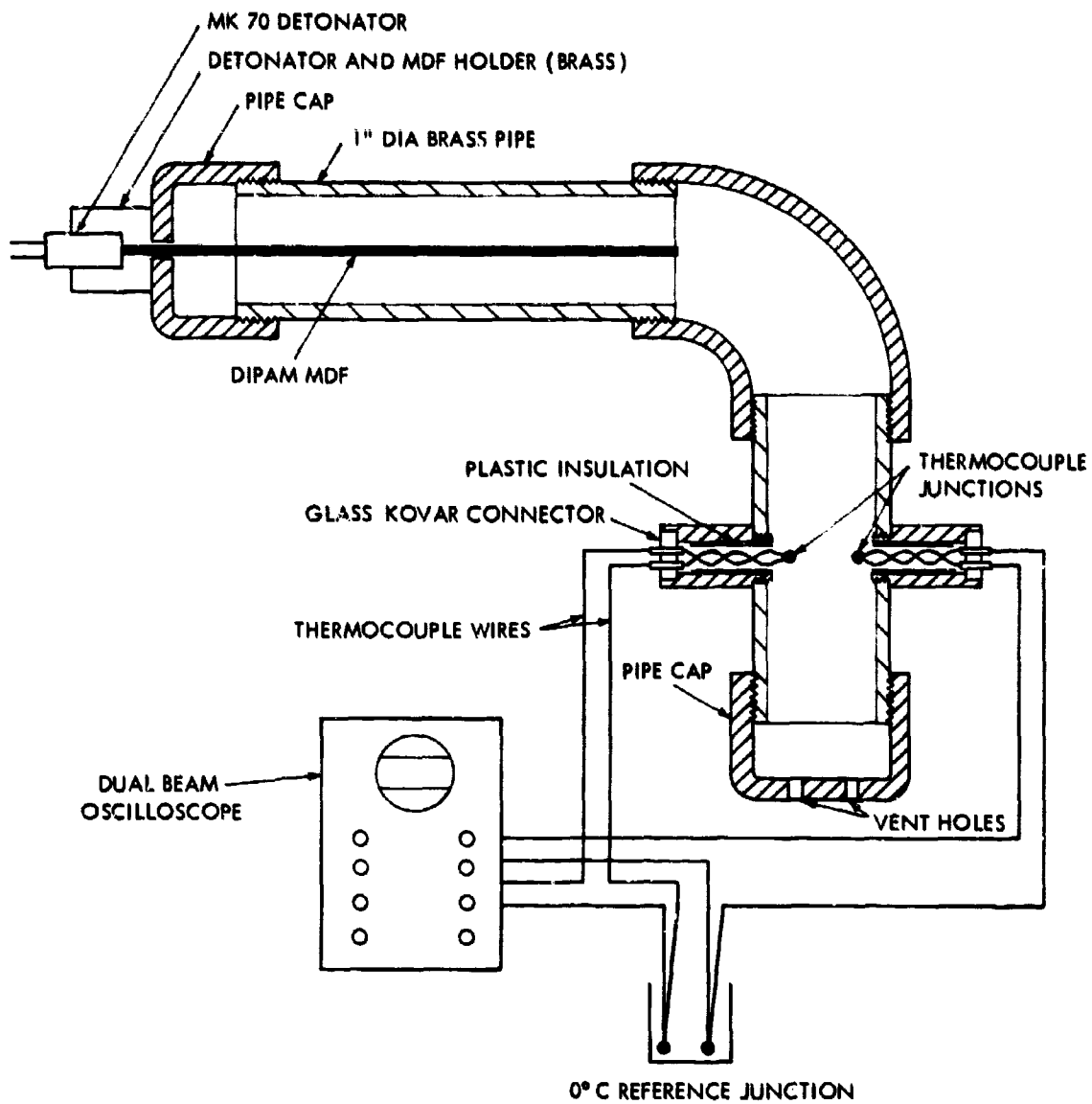
FIG. 3 TEMPERATURE STUDY APPARATUS

10

UNCLASSIFIED

TABLE III

TEMPERATURE STUDY RESULTS

Core Load	Wt. DIPAM	ΔT	Avg. ΔT
2.1 grain/ft	1.05 grain	6.0°	
2.1 grain/ft	1.05 grain	10°	6.7°
2.1 grain/ft	1.05 grain	4.0°	
10 grain/ft	5 grains	46.5°	
10 grain/ft	5 grains	46°	41.7°
10 grain/ft	5 grains	32.5°	
15 grain/ft	7.5 grains	76°	
15 grain/ft	7.5 grains	63°	63°
15 grain/ft	7.5 grains	64°	
15 grain/ft	7.5 grains	49°	
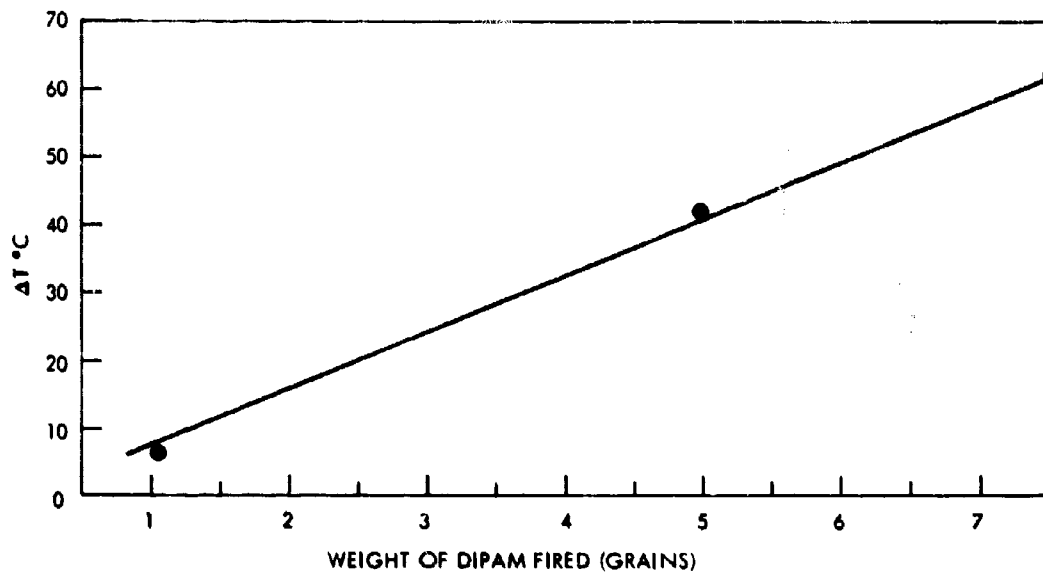
FIG. 4 TEMPERATURE STUDY RESULTS

We surmise that the temperature trace observed in sample D was a complete anomaly not only on the basis of the reasoning above, but also because from Figure 2 it can be seen that the cooling time constant for D was much shorter, indicating a greater rate of cooling. Yet we can see no way that there could have been enough of a physical change in the experiment to cause such an alteration in the cooling rate.

CONCLUSIONS

Figure 5 shows the approximate relation of the CO_2/CO mole ratio versus the O_2/HE mole ratio for DIPAM and RDX. Other oxygen deficient explosives would be expected to show similar curves. As the oxygen available upon detonation decreases, the products contain greater amounts of carbon monoxide and free carbon. The appearance of sooty black solid products can be used as a qualitative indication (for DIPAM) that the CO_2/CO ratio in the gaseous products is fairly low. This, of course, is the undesirable tendency since the body can tolerate about 400 times as much CO_2 as CO for extended lengths of time.*

Although we do not have any data which tell us exactly what reactions do take place, we do have a basis for making pessimistic estimates of the toxicity due to CO_2 and CO. The following scheme is suggested:

   a. Determine the ambient temperature and pressures, and volume of the life support space into which product gases may be vented.

   b. Determine the number of moles of explosive which, by the design of the system, may produce the product gases.

   c. Estimate the O_2/HE mole ratio for the gases sufficiently close to the explosive to enter into afterburning reactions.

   d. Assume that all of the carbon in the molecule of explosive will yield either CO or CO_2, or a combination of the two. The most pessimistic assumption is, of course, that it will all be converted to CO. However, the graph of Figure 5 will permit a more realistic estimate.

   e. From steps (b) and (d) above compute the number of moles of CO_2 and/or CO evolved.

---

*Submarine atmospheric environment limits are 10,000 ppm of CO_2 for 90 days and 25 ppm of CO for 90 days at 15 psia (NavShips 250-694-1, Rev. 1 of Sep 1962). It is the opinion of authorities at the National Naval Medical Center that these limits would represent a greater margin of safety at an ambient pressure of 7 psia.

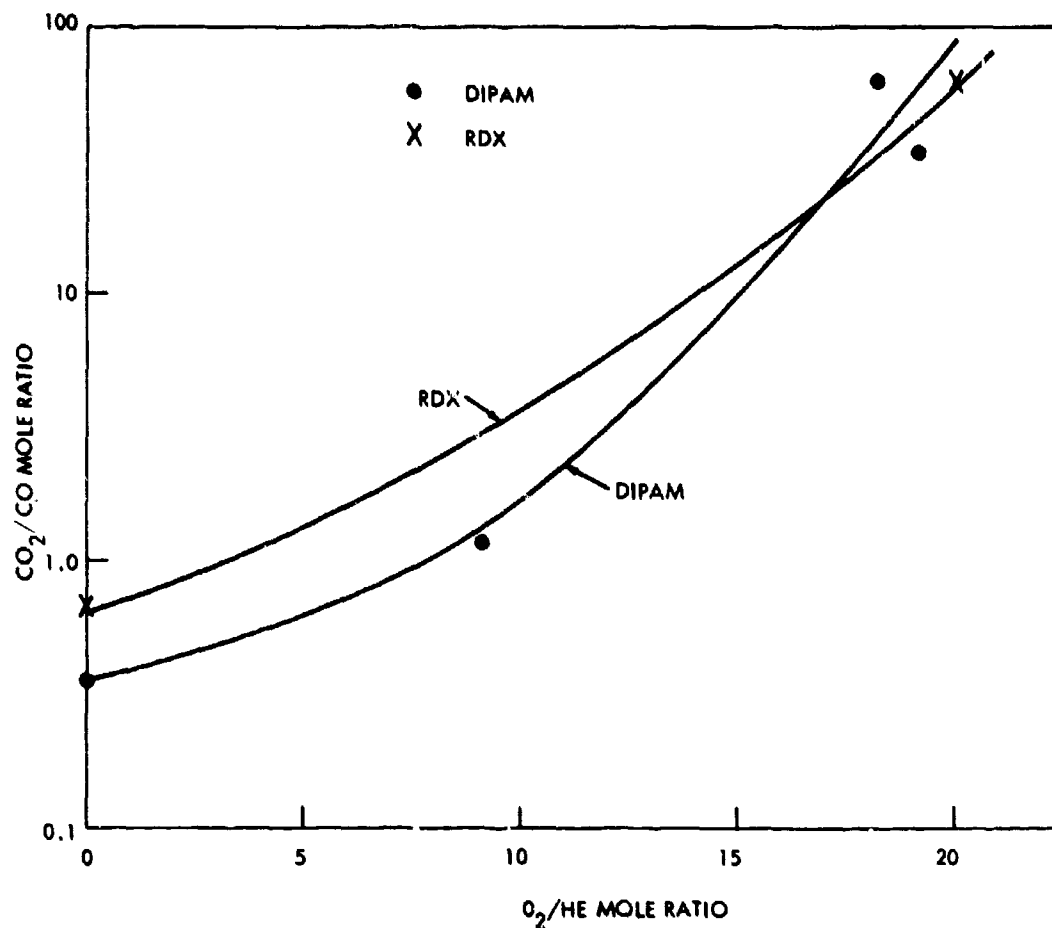FIG . 5 EFFECT OF ATMOSPHERIC OXYGEN ON CO_2/CO BALANCE

f. From step (a) compute the number of moles of air
    already present.

g. From steps (e) and (f) compute the contamination levels.

NOTE: Remember that the toxicity levels are quoted on a
       volume basis.

Oxygen deficient explosives confined in structures such as
MDF react with oxygen in the atmosphere during and/or immediately
after detonation. Products of detonation vary with the amount
of oxygen available. Both DIPAM and RDX showed considerable
formation of carbon monoxide when fired in an absence of
atmospheric oxygen, as might be the case in space or high-
altitude applications. Depending on the total amount of
explosive, the products of explosion of MDF loaded with oxygen
deficient explosive could be of sufficient carbon monoxide
content to be harmful to human beings near by. It should be
remembered that both CO_2 and CO are toxic and that, whatever the
high explosive used, there will be a formation of both of these
gases as well as other noxious or toxic materials.

RECOMMENDATIONS

A more thorough study of the detonation products of oxygen
deficient explosives, including a quantitative determination of
all gaseous and solid products, should be very informative. We
would expect to be able to demonstrate that greater quantities
of explosives would be permissible since we do not expect all
the carbon atoms to be converted to CO_2 and/or CO. Detonation
products for other explosives under other conditions and
atmospheres should give valuable data useful in the better under-
standing of the detonation behavior of explosives. No studies
have been made on the nitrogen oxides and metal products that
also can present toxic hazards. For a thorough study, those
should not be overlooked.

DOCUMENT CONTROL DATA · R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY *(Corporate author)*	2a REPORT SECURITY CLASSIFICATION
Naval Ordnance Laboratory White Oak, Silver Spring, Md.	CONFIDENTIAL 2b GROUP 4

3 REPORT TITLE

Detonation Products of Oxygen Deficient Explosives (U)

4 DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5 AUTHOR(S) *(Last name, first name, initial)*

Root, C. B.
Ayres, J. N.

6 REPORT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
25 October 1965	15	0

8a CONTRACT OR GRANT NO	9a ORIGINATOR'S REPORT NUMBER(S)
b PROJECT NO	
c Task NOL-787/NASA	NOLTR 65-114
d	9b OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* ---

10 AVAILABILITY LIMITATION NOTICES

~~Re...~~ government agencies only.

11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY
	Naval Ordnance Laboratory Silver Spring, Md.

13 ABSTRACT

Mild detonating fuse containing oxygen deficient explosives, such as a high temperature explosive and RDX, showed considerable formation of carbon monoxide when fired in the absence of atmospheric oxygen. As might be the case in space or high altitude applications, and depending on the total amount of explosive, the detonation products of MDF loaded with oxygen deficient explosives could contain sufficient carbon monoxide to be harmful to human beings. A method is given for estimating the toxicity from carbon monoxide and carbon dioxide when oxygen deficient explosives are detonated in confined structures. (Abstract unclassified)

DD FORM 1473
1 JAN 64

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Boosters, Mild Detonating Fuse						
Couplers, Mild Detonating Fuse						
Detonation Products of Explosives						
Fuses, Mild Detonating						
Explosives						
Explosives, oxygen deficient						
Airplane, F-111 crew module						
Toxicity, explosive products						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (corporate author) issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (either by the originator or by the sponsor), also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

  (1) "Qualified requesters may obtain copies of this report from DDC."

  (2) "Foreign announcement and dissemination of this report by DDC is not authorized."

  (3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through

    _____ ."

  (4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through

    _____ ."

  (5) "All distribution of this report is controlled. Qualified DDC users shall request through

    _____ ."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring (paying for) the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U)

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 65-114)
DETONATION PRODUCTS OF OXYGEN DEFICIENT
EXPLOSIVES (U), by C. B. Root and J. N. Ayres.
25 Oct. 1965. 15p. illus., tables. NOL task
787/NASA.
CONFIDENTIAL

Mild detonating fuse containing oxygen defi-
cient explosives showed considerable formation
of carbon monoxide when fired in absence of
atmospheric oxygen. Since this might be the
case in space or high altitude applications,
the detonation products of MDF loaded with
oxygen deficient explosives could contain suf-
ficient carbon monoxide to be harmful to man-
kind. A method is given for estimating the
toxicity from carbon monoxide and carbon di-
oxide when oxygen deficient explosives are
detonated in confined structures.

1. Fuses,
   Mild
   detonating
2. Explosions -
   Toxicity
I. Title
II. Root,
   Charles B.
III. Ayres,
   James N.,
   jt. author
IV. Project

Abstract card is
unclassified.